

Plastic Cup Traps Equipped with Light-Emitting Diodes for Monitoring Adult *Bemisia tabaci* (Homoptera: Aleyrodidae)

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ABSTRACT Equipping the standard plastic cup trap, also known as the CC trap, with lime-green light-emitting diodes (LED-plastic cup trap) increased its efficacy for catching *Bemisia tabaci* by 100%. Few *Eretmocerus eremicus* Rose and Zolnerowich and *Encarsia formosa* Gahan were caught in LED-plastic cup traps. The LED-plastic cup traps are less expensive than yellow sticky card traps for monitoring adult whiteflies in greenhouse crop production systems and are more compatible with whitefly parasitoids releases for *Bemisia* nymph control.

KEY WORDS *Bemisia tabaci*, *Eretmocerus*, *Encarsia*, LED-plastic cup trap, yellow sticky card trap

Bemisia tabaci (GENNADIUS) is a polyphagous pest and virus vector that complicates conventional control efforts. A recently described *Bemisia tabaci* biotype B (*Bemisia argentifolii* Bellows and Perring) has an expanded host range and attacks a larger number of field and greenhouse plants (Perring 2001). In commercial greenhouse production, aphelinid parasitoids have been used to control the greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) (van Lenteren et al. 1997) and *Bemisia* spp. (Gerling 1990). Yellow sticky card (YC) traps are also used by growers to monitor and to reduce adult whiteflies and other pests in greenhouses, but they also catch whitefly-associated parasitoids and their use conflicts with parasitoid efficacy. We have developed a plastic cup trap with a yellow base, also known as the CC trap, which is selective for adult *B. tabaci* and catches few parasitoids of *B. tabaci* (Chu and Henneberry 1998, Hoelmer et al. 1998). The trap has been used for monitoring *B. tabaci* adult populations year round (Chu et al. 2001). The objective of this study was to determine the potential use of the plastic cup trap equipped with a light-emitting diode (LED) in greenhouses in conjunction with releases of the parasitoids, *Eretmocerus eremicus* Rose and Zolnerowich and *Encarsia formosa* Gahan, to control *Bemisia* nymphs.

Materials and Methods

Commercial Greenhouse Experiment

Greenhouse and Plant Culture. A 528-m² (16-m wide × 33-m long) commercial size greenhouse at the

University of Arizona in Tucson, AZ, was used for the experiment. It housed seven 30-m long rows of matured vine tomatoes (*Lycopersicon esculentum* L., variety *commune*) in the center, one row of matured vine bell pepper (*Capsicum annuum* L.) on one side, and one row of cucumber (*Cucumis sativas* L.) on the other side. Nutrients were supplied with a diluted complete nutrient solution (pH 5.0) through a drip system. The tomatoes were a mixture of varieties: Blitz, Rapsodie, Quest, and Mariachi. The pepper and cucumber varieties were Mondo and Cazorla, respectively. Rows were 1.22 m apart. The growth medium was plastic bagged rockwool material. Plants were ≈3.0 m tall and were trained on a 3.3-m high wire trellis. Each tomato row had two sub-rows, 0.61 m apart. We divided the tomato rows #2, #5, and #8 into eight plots, 7.6-m long each. Temperature and humidity were maintained at 25°:16°C (day: night) and 50–80%, respectively. No artificial lights were provided.

Experiment 1. A randomized complete block design was used to compare the plastic cup trap with a YC trap. The treatments were replicated four times. The plastic cup trap treatment was a group of 22 standard plastic cup traps (Fig. 1A) with the deflector removed and with a Tanglefoot coating on the inside of the trap top (coated plastic cup trap, Fig. 1B). In a preliminary cage study, we found that the catches of *B. tabaci* adults in one standard plastic cup trap were similar to the catches of a 42-cm² YC trap. The 22 plastic cup traps were suspended on the wire that also supported the tomato plants, with eleven traps per sub-row. Traps were spaced evenly, with the yellow-colored trap base leveled with plant terminals. The YC trap was placed at the center of the plot with the bottom side leveled with plant terminals. By the completion of the test after 7 d, trap bases were 10–15 cm below

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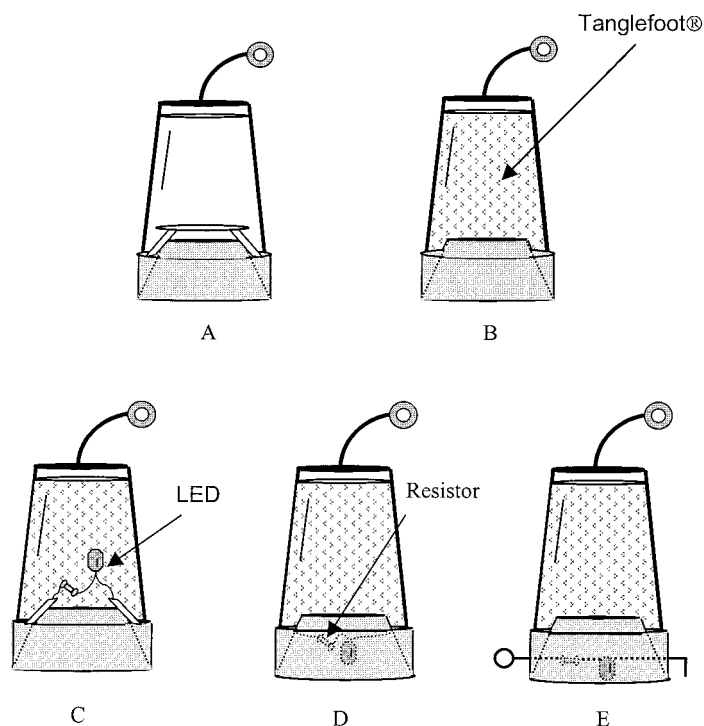


Fig. 1. The plastic cup trap: (A) standard, (B) coated, (C) light-emitting diode (LED) equipped with the LED upward, (D) LED downward, (E) LED downward-lo.

terminals. *Bemisia tabaci* in the greenhouse were most likely from cotton plants in the surrounding area. Control measures taken were the application of the insecticides Azatin (Azadirachtin) and M-Pede (potassium salt of fatty acids), and the release of 1,500 each of *E. eremicus* and *En. formosa*. The traps were installed on 19 April 2001 and trap catches were counted 7 d later.

Research Greenhouse Experiment

Cages and Plant Culture. Eight small wood ($60 \times 140 \times 164$ cm, l \times w \times h) and six large aluminum cages ($278 \times 278 \times 278$ cm) covered with 72-mesh screen were used in the experiments. Plants in each small cage were five 4–5 true leaf potted green bush beans (*Phaseolus vulgaris* L. variety *humilis*) cultivar Landreth (NK Lawn & Garden Co., Chattanooga, TN). Plants in each large cage were 24 mature tomato cultivar ACE 55 plants (Petoseed, Saticoy, CA). Tomato plants had 12–15 nodes and were in the fruiting stage. All plants were watered daily with a diluted nutrient solution (15–5–15 Cal-Mag, Scotts Co., Marysville, OH).

Experiments. Experiments on light-emitting diode-equipped plastic cup traps were conducted in cages in greenhouses in Phoenix, AZ, using randomized complete block designs. There were four experiments. The six large cages were used for experiments 2, 3, and 4; and the eight small cages for experiment 5. The LED-plastic cup traps were the coated plastic cup traps

equipped with upward- (Fig. 1C), downward- (Fig. 1D), or downward-lo (Fig. 1E)-directed, 530 nm lime-green LEDs (Nichia America Corp, Mountville, PA). For upward-directed LED only, the top of the trap was covered with white paper to reflect the LED light. Electricity was from 110 V wall-plug units with a home-made transformer to obtain 6 V DC. Traps were 120 and 270 cm apart in each small and large cage, respectively, facing each other. Traps were 10–15 cm above plant terminals in the small cages and 10–15 cm below plant terminals in the large cages.

Experiment 2 compared trap catches between LED-plastic cup traps equipped with upward- and downward-directed LED. Experiment 3 compared trap catches between LED-plastic cup traps with downward-directed LED and coated plastic cup traps. Experiment 4 compared trap catches between LED-plastic cup trap with downward-directed LED and YC traps. Experiment 5 compared trap catches between LED-plastic cup traps with downward- and downward-lo-directed LED. One thousand adult *B. tabaci* were released daily in each small cage for experiment 5. No *B. tabaci* adults were released into the large cages for experiments 2, 3, or 4 because the tomato plants were highly infested with *B. tabaci*. Six hundred *E. eremicus* and 100 *En. formosa* were released into each cage for experiment 3; and 900 *E. eremicus* and 490 *En. formosa* for experiment 4. Traps were replaced and trap catches were counted daily for experiments 2–5. Numbers of sampling dates were five, four, eleven, and eight for experiments 2, 3, 4, and 5, respectively. The

Table 1. Mean \pm SE numbers of *Bemisia tabaci* and *Eretmocerus* and *Encarsia* caught with light-emitting diode equipped (LED) plastic cup and yellow sticky card (YC) traps in cage experiments with tomato and bush bean plants

Exp.	Trap type	LED direction	No. adults/trap/day ^a		
			<i>B. tabaci</i>	<i>E. eremicus</i>	<i>En. formosa</i>
1	YC	NA ^b	6.7 \pm 1.7a ^c	4.1 \pm 0.6a	0.7 \pm 0.3a
	Coated ^d plastic cup trap	NA	5.5 \pm 1.4a	0.0 \pm 0.0b	0.4 \pm 0.1a
2	LED-whitefly	Up	1,019.3 \pm 105.7b	— ^e	—
	LED-whitefly	Down	1,602.3 \pm 217.0a	—	—
3	Coated plastic cup trap	NA	497.7 \pm 91.0b	1.8 \pm 0.4b	0.0 \pm 0.0a
	LED-whitefly	Down	3,055.3 \pm 371.3a	33.4 \pm 11.5a	0.2 \pm 0.1a
4	YC	NA	232.4 \pm 75.2a	39.2 \pm 2.8a	81.6 \pm 4.1a
	LED-whitefly	Down	189.2 \pm 63.8a	2.8 \pm 0.4b	5.3 \pm 0.6b
5	LED-whitefly	Down	22.0 \pm 2.3a	—	—
	LED-whitefly	Down-lo	24.1 \pm 3.3a	—	—

^a Means within a column of a given experiment not followed by the same letter are significantly different (*t*-test, *P* = 0.05). *F* = 1.2, 38.6, and 1.0 for *B. tabaci*, *E. eremicus*, and *En. formosa* and *df* = 1, 3 for experiment 1; *F* = 18.1 for *B. tabaci* and *df* = 1, 5 for experiment 2; *F* = 61.4, 7.8, and 4.3 for *B. tabaci*, *E. eremicus*, and *En. formosa*, respectively, and *df* = 1, 5 for experiment 3; *F* = 0.5, 158.6, and 345.0 for *B. tabaci*, *E. eremicus*, and *En. formosa*, respectively, and *df* = 1, 5 for experiment 4; and *F* = 0.2 and *df* = 1, 7 for experiment 5.

^b NA = not applicable.

^c Adults/trap/week.

^d The inside surface of the trap was coated with an insect adhesive.

^e No data.

study was conducted from 13 February 2001–24 May 2002. During the experimental periods, mean minimum temperatures ranged from 10.3 \pm 0.6 to 23.9 \pm 0.4°C and maximum temperatures ranged from 29.0 \pm 0.5 to 48.5 \pm 0.7°C. Mean relative humidity ranged from 24.8 \pm 0.8 to 80.2 \pm 1.2%.

Statistical Analyses. Numbers of trap catches were averaged over sampling dates per coated plastic cup trap and per 100-cm² YC trap per week for experiment 1, and per LED-plastic cup trap and per 100-cm² YC trap per day for experiments 2–5. Data were analyzed using analysis of variance and means were separated using *t*-tests.

Results and Discussion

Similar trap catches of *B. tabaci* and *En. formosa* were found for the YC and coated plastic cup traps in the commercial greenhouse experiment, although the YC traps caught significantly more *E. eremicus* compared with the coated plastic cup traps (Table 1, experiment 1). Trap catches of *B. tabaci* were 1.6 times higher for LED-plastic cup traps with the downward-directed LED compared with the upward-directed LED (experiment 2) and 6.1 times higher for LED-plastic cup traps with the downward-directed LED compared with the coated plastic cup traps (experiment 3). Trap catches of *B. tabaci* for the LED-plastic cup trap with the downward directed LED were not significantly different from catches on YC traps (experiment 4) and catches of *B. tabaci* in downward-directed and downward-lo-directed LED traps also were not significantly different (experiment 5). The LED-plastic cup trap catches were 18.6 times higher for *E. eremicus* compared with the coated plastic cup trap, but not *En. Formosa* (experiment 3). Trap catches of *E. eremicus* or *En. formosa* in LED-plastic cup traps were 7% of the catches on YC traps (experiment 4).

We reported earlier that the standard plastic cup trap caught half of the adult *B. tabaci* compared with one 100-cm² YC trap (Hoelmer et al. 1998). Results of this study showed that equipping the standard plastic cup trap with a lime-green LED increased its efficacy for catching *B. tabaci* by 100%. *B. tabaci* generally do not fly at night (Liu et al. 1994, Chu et al. 1998), thus, the increased catches of *B. tabaci* in LED-plastic cup traps indicate they responded to lime green light (peak 530 nm). Similar to the standard plastic cup trap, the LED-plastic cup trap seems to be compatible with *B. tabaci* associated parasitoids because catches of adult *Eretmocerus* and *Encarsia* were negligible. Adult *Eretmocerus* was also attracted to green light (plant cue, Blackmer and Cross 2001), but could have soon left the light source when they failed to find the host, *Bemisia* nymphs. Also, the parasitoids did not fly toward the skylight under greenhouse or field conditions (Hoelmer et al. 1998, unpublished data).

Results of the study indicate that one LED-plastic cup trap may have the potential efficacy of one 100-cm² YC trap. A conventional 15 \times 30-cm YC trap has a sticky surface of 900 cm² when both sides are exposed. Comparable trap catches could be achieved with nine LED-plastic cup traps. When mass produced, each LED-plastic cup trap costs approximately \$1. The LED can be used for a long time because of low voltage and low current input for LED activation. The LED-plastic cup trap is also durable, requiring only an occasional trap top replacement that costs \approx 7 cents apiece. YC traps cost \$1 each (Olson Products, Medina, OH) and must be replaced once a week for highest trapping efficacy. In greenhouse farming in which *B. tabaci* and possibly other whitefly species are economic pests, a monetary advantage from the use of the LED-plastic cup traps would occur rapidly. Our results suggest the compatibility of LED-plastic cup traps in greenhouses in which supplement parasitoids have been released for *B. tabaci* control. Further tests

with greenhouse whiteflies, *T. vaporariorum*, and *Encarsia* parasitoids are needed.

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